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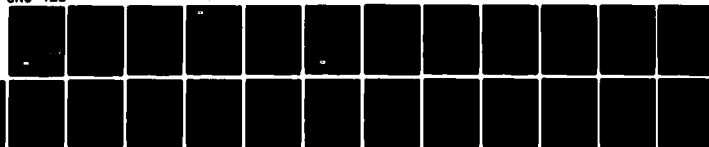
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RATING ASSIGNMENTS TO ENHANCE RETENTION

James S. Thomason

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1. Enclosure (1) is forwarded as a matter of possible interest.
2. This Research Contribution was prepared in connection with CNA's study of Personnel Management in the All Volunteer Force. It assesses the gain that could be available to the Navy by assigning men to ratings to maximize first-term retention. Reassignment of more than 28,000 recruits to 37 major Navy ratings is simulated. Rating-specific survival estimates and constraints the Navy faced in assigning these men are used. An appreciable gain is demonstrated. A procedure to exploit rating-specific survival estimates in recruit classification is recommended.
3. Research Contributions are distributed for their potential value in other studies and analyses. They do not necessarily represent the opinion of the Department of the Navy.

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RATING ASSIGNMENTS TO ENHANCE RETENTION

James S. Thomason



Institute of Naval Studies

CENTER FOR NAVAL ANALYSES

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SUMMARY

First-term survival gains from exploiting rating-specific survival estimates in recruit classification were analyzed. The analysis required a simulation of the Navy's assignment process. The model devised for this purpose hypothetically reassigned more than 28,000 CY 1973 recruits to 37 ratings. All recruits had to be reassigned and all ratings filled. Recruits did not have to be reassigned to their original ratings. The model maximized the number of recruits who would complete four years of service, subject to the same constraints faced in their original assignments.

The simulated reassignment produced a four-year survival rate of 73 percent. The actual rate was 67 percent.

Further work on the survival estimates is underway to check their stability in a later cohort of recruits, and to extend their coverage to other Navy ratings. The goal is to provide rating-specific survival probabilities for recruit classification and assignment that will increase first-term retention.

BACKGROUND

Enlisted retention is a continuing issue in Navy manpower planning. An earlier CNA study showed that changes in assignment procedures could improve first-term retention (reference 1). Four-year survival rates were estimated for 28,137 recruits who enlisted in CY 1973 and served in 37 major ratings.¹ Recruits were first classified by pre-service/early in-service characteristics.

Regression analysis was then used to estimate the effects of these characteristics on 4-year survival. The effects often differed by rating, particularly with respect to age and educational level, boot camp, and participation in the delayed entry program. This means that an assignment procedure during recruit classification could exploit these rating differences to improve the overall survival rate of a cohort.

¹ These estimated survival rates are conditional on the recruit surviving the first 6 months of service. Until then, we could not identify the rating in which he would actually serve. For details, see reference 1.

REASSIGNMENT SIMULATION

To assess potential survival gains required a simulation of the Navy's assignment process using the different rating estimates. An optimization model was developed to maximize the number of 4-year survivors by reassigning the 28,137 CY 1973 recruits to 37 ratings.¹ The model imposed the same rating eligibility constraints faced when the recruits were initially assigned.

RECRUITS, RATING SLOTS, AND SURVIVAL PROBABILITIES

The 28,137 recruits were first divided into 48 mutually exclusive categories (input cells) based on their characteristics. Similarly, the 28,137 rating slots were distributed into 14 relatively homogeneous groups of the 37 ratings. Each input cell contained as many recruits of that type as were found in the group (see table 1). Each rating group had as many rating slots as there were recruits who actually served in it (see table 2).

Estimates of the probability (P) that a recruit from any given input cell (i) would survive 4 years if assigned to any one of these 14 rating groups (j) were taken from reference 1. Table 3 shows some of them. All recruits from a given input cell were assumed to have equal chances of surviving 4 years in a given rating group. Appendix A describes the rationale for this assumption.

OBJECTIVE FUNCTION AND CONSTRAINTS

The objective function maximized in the model was:

$$\sum_{i=1}^{48} \sum_{j=1}^{14} X_{ij} \cdot P_{ij} ,$$

where

P_{ij} = the probability that a recruit from input cell "i" will survive 4 years in rating group "j";

¹A standard linear program was used, based on the TEMPO Mathematical Programming System. TEMPO is the Burroughs 7700/6600 adaptation of the MPS linear programming system. See reference 2 for details. CDR Charles Zuhoski provided extremely valuable help in implementing the program.

TABLE 1

CY 1973 NAVY RECRUIT SAMPLE USED IN REASSIGNMENT TEST (N=28, 137)

Recruit training location	Age	4-year term				6-year term			
		^a							
		D.E.P. HSG	NHSG	Direct HSG	Ship NHSG	D.E.P. HSG	NHSG	Direct HSG	Ship NHSG
Great Lakes	> 18	1168	487	3751	282	249	0	874	4
	< 18	208	862	709	274	46	0	180	0
San Diego	> 18	1310	399	3036	196	547	0	1444	5
	< 18	189	529	454	171	78	0	239	0
Orlando	> 18	1778	265	4479	162	569	0	1215	6
	< 18	440	463	700	103	95	0	171	0

^a Delayed Entry Program.

TABLE 2
RATING SLOTS AVAILABLE
IN REASSIGNMENT TEST

<u>Rating group</u>	<u>Ratings</u>	<u>Rating slots</u>
BT	BT	1,729
MM	MM	2,725
EM/IC	EM, IC	2,142
EN	EN	1,030
HT	HT	1,381
ET/FT	ET, FT	2,128
Sensor	ST, EW, OT	1,045
RM/CT	RM, CT	1,646
Aviation Weapons	AT, AW, AQ, AC, AX	2,109
Aviation Maintenance	AM, AD, AE, AO	3,512
Aviation Support	AS, PR, AB	1,096
Medical	DT, HM	3,445
Logistics	MS, SK, AK, DK, SH	2,580
Administration	PN, YN, AZ, PC, AG	<u>1,570</u>
Totals	37 ratings	28,137

TABLE 3

BASE SURVIVAL CHANCES AND EFFECTS OF
PRE-ASSIGNMENT VARIABLES ON 4-YEAR SURVIVAL^a

Rating group	Base (%)	Change from base (% points)				
		Age 17	RTC		EDLT12	D.E.P.
			GLAKES	SDIEGO		
BT	56	.	.	.	-13	+5
MM	57	-6	.	.	.	+8
EM/IC	67	.	.	-5	.	.
EN	56	.	-7	.	+9	+12
HT	72	.	.	-6	-14	.
ET/FT	78	.	.	-9	.	+4
Sensor	83	.	-8	-6	.	+8
RM/CT	70	.	.	.	.	.
Aviation Weapons	76	.	-12	-9	.	+8
Aviation Maintenance	73	-6	-4	-4	-6	+5
Aviation Support	60	.	.	.	-10	+11
Medical	78	-4	-16	-10	-8	.
Logistics	58	-5	-5	.	-9	+8
Adminis- tration	66	.	.	.	.	.

^aThe base case recruit in each group is 18 years old, had 12 or more years of education, was not DEPped, and attended boot camp at Orlando. See reference 1, table 2, for details.

and

X_{ij} = the number of recruits from cell "i" to be assigned to rating group "j".

In short, the optimization model was structured to identify the set of X_{ij} s that maximizes the objective function, given the P_{ij} s from reference 1 and subject to explicit constraints discussed below.

Quantity Constraints

The basic quantity requirements were that all recruits be assigned and all rating slots be filled. Other quantity constraints specified the number of recruits available from each input cell (as in table 1) and the numbers of rating slots available in each rating group (as in table 2) as follows:

$$\sum_{j=1}^{14} X_{ij} \leq IC_i, \quad i = 1, 2, \dots, 48$$

where IC_i = the total number of recruits available for assignment from input cell i;

$$\sum_{i=1}^{48} X_{ij} \geq RG_j, \quad j = 1, 2, \dots, 14,$$

where RG_j = the total number of available rating slots in rating group j.

Quality Constraints

The Navy has minimum entry standards for each rating. To simulate the most important ones, recruits were classified by whether or not their Basic Test Battery composite scores qualified them for particular ratings (table 4).

For example, if only 10 percent of the recruits in input cell 1 were qualified to enter rating group 1, then a maximum of 10 percent of the population of input cell 1 was eligible to enter

TABLE 4
RATING ELIGIBILITY REQUIREMENTS
BY RATING GROUP (CY 1973)

<u>Rating group</u>	<u>BTB score needed to enter^a</u>	<u>Minimum percentages of recruits who had to meet BTB^b</u>
BT	G+M+SP \geq 156	94
MM	G+M+SP \geq 156	80
EM/IC	G+M+SP \geq 156	84
EN	G+M+SP \geq 156	90
HT	G+M+SP \geq 156	91
ET/FT	A+2E \geq 171	80
Sensor	G+A \geq 110	70
RM/CT	G+A \geq 100	90
Aviation Weapons	G+A \geq 110	74
Aviation Maintenance	G+M+SP \geq 156	89
Aviation Support	G+M+SP \geq 156	90
Medical	G+A \geq 100	89
Logistics	G+A \geq 100	91
Administration	G+A \geq 100	99

^aAdapted from reference 3, CNS 1039, Enlisted Selection Strategies, September 1974, by Robert F. Lockman, appendix B, table B-9.

^bThese are the percentages of these recruits who in fact served in these rating groups and satisfied the BTB minimums shown here.

rating group 1.¹ In sum, a set of maximum flows -- from each of 48 input cells to each of 14 rating groups -- were explicitly imposed on the model to simulate minimum entry standards.

The Navy also requires a 6-year service obligation (6 YO) from recruits in ratings involving the advanced electronics and nuclear fields. Our model forced as many 6-year obligors into a given rating group as were originally found there. Table 5 shows the 6 YO distribution.

TABLE 5
MINIMUM NUMBERS OF 6-YEAR OBLIGORS
REASSIGNED TO RATING GROUPS

<u>Rating group</u>	<u>Minimum 6 YOs reassigned</u>	
	<u>Number</u>	<u>% of all slots</u>
MM	1363	50
EM/IC	857	40
Sensor	522	50
ET/FT	1490	70
RM/CT	165	10
Aviation Weapons	633	30

The test procedure consisted of a run of the (TEMPO) linear program. This resulted in a set of "reassignments" -- of 28,137 recruits to 28,137 rating slots -- that maximized the expected number of four-year survivors while satisfying the quantity and quality constraints.

¹ Actually, this was more complex than the discussion may suggest. Some of these recruits did not seem qualified for any ratings by BTB criteria; some other recruits may or may not have been qualified -- not enough BTB data was available on them to know. To deal with this, we devised constraints to allocate these "residual" recruits to rating groups based on the proportions of recruits in each rating who did not attend A schools for that rating (see table 4).

RESULTS

An improved overall first-term survival rate was not inevitable. Even though the Navy had no rating survival estimates in 1973-74, classifiers might have informally evolved comparable assignment rules anyway. Or, the survival patterns in reference 1 simply might not have offered much to exploit. Or both.

However, table 6 shows that the 73 percent retention rate in the reassignment test was noticeably higher than the actual rate of 67 percent. This means that there are gains to be realized by assigning recruits to ratings based on their expected survival chances in given ratings. Table 7 displays the specific assignments that led to an increased overall survival rate. (Table 8, for comparison, shows the way the Navy actually distributed these same recruits among rating groups.) There is nothing implausible or impractical in the results.

For example, look at the first row of table 7. It shows that of men reassigned to be BTs, all had at least 12 years of education, all were at least 18 years old at entry, all were in the delayed entry program, but none was a 6 YO. Further, most of these men went to boot camp at Great Lakes and none went to Orlando.

Generally, the most interesting results are the extremes. For one thing, the solution placed no high school graduates (HSGs) as enginemen (EN), no delayed entry recruits in logistics ratings, and at least seven rating groups got few if any men from one or even two of the boot camps. These results occur because the model took maximum advantage of the benefit for 4-year survival of placing those types of recruits in other ratings. Similarly, the model placed as many HSGs as possible in six ratings/groups: BT, HT, ET/FT, Aviation Maintenance, Aviation Support, and Medical.

If non-HSGs hurt survival in a rating group, we would expect a proper model to assign them to it only if HSGs either enhance the overall cohort survival rate more when assigned elsewhere or are not available. Table 9 shows the 6 rating groups where non-HSGs hurt survival. The model placed higher proportions of HSGs in these groups than were actually assigned to them. Moreover, only non-HSGs were assigned to the rating in which non-HSGs enhanced survival, HT.

Clearly, therefore, this model reassigns to exploit the survival effects associated with different educational levels. But even if being a HSG helped survival, other things equal, HSGs did not always survive more often in a given rating group than non-HSGs. Table 3 showed, for instance, that a delayed entry non-HSG survived about as well as a direct-shipped HSG in the logistics group.

TABLE 6
RETENTION RESULT FROM REASSIGNMENT
COMPARED TO ACTUAL RETENTION
(CY 73 sample)

	<u>Number of recruits assigned</u>	<u>4-Year survivors</u>	<u>Overall survival rate</u>
Actual	28,137	18,981	.67
Test	28,137	20,596	.73

TABLE 7
DETAILED RESULTS OF REASSIGNMENT TEST

<u>Rating group</u>	<u>% HSG</u>	<u>% 6YO</u>	<u>% GE 18</u>	<u>% DEP</u>	<u>% RTC</u>		
					<u>GL</u>	<u>SD</u>	<u>ORL</u>
BT	100	0	100	100	87	13	0
MM	95	50	100	100	60	40	0
EM/IC	58	40	55	93	62	37	1
EN	0	0	42	65	26	62	12
HT	100	0	61	7	65	0	35
ET/FT	100	70	83	89	50	21	29
Sensor	74	50	72	85	6	36	58
RM/CT	84	52	64	44	32	62	2
Aviation Weapons	95	30	69	100	0	0	100
Aviation							
Maintenance	100	0	100	96	4	59	37
Aviation Support	100	0	18	100	58	30	12
Medical	100	0	95	63	0	0	100
Logistics	87	0	94	0	12	61	27
Administration	55	0	56	54	45	55	0

TABLE 8
ORIGINAL ASSIGNMENTS OF CY 1973 SAMPLE

<u>Rating group</u>	<u>% HSG</u>	<u>% 6YO</u>	<u>% GE 18</u>	<u>% DEP</u>	<u>% RTC</u>		
					<u>GL</u>	<u>SD</u>	<u>ORL</u>
BT	59	0	64	44	42	29	28
MM	89	50	81	65	31	37	33
EM/IC	93	40	84	79	28	29	43
EN	89	0	79	72	39	21	40
HT	79	0	74	68	37	22	41
ET/FT	88	70	85	68	30	32	39
Sensor	85	50	84	68	20	36	44
RM/CT	86	10	78	60	32	29	39
Aviation Weapons	82	30	84	68	22	50	28
Aviation Maintenance	79	0	74	53	26	32	41
Aviation Support	64	0	67	49	45	35	21
Medical	89	0	84	77	38	19	43
Logistics	76	0	75	66	40	23	37
Administration	89	0	85	70	27	40	33

TABLE 9

REASSIGNMENTS TO EXPLOIT SURVIVAL
DIFFERENCES IN EDUCATIONAL LEVEL

Rating group	% HSG		Effect on survival of less than 12 years of educ. (in percentage points ^c)
	Original ^a	Reassigned ^b	
BT	59	100	-13
MM	89	95	.
EM/IC	93	58	.
EN	89	0	+9
HT	79	100	-14
ET/FT	88	100	.
Sensor	85	74	.
RM/CT	86	84	.
Aviation Weapons	82	95	.
Aviation Maintenance	79	100	-6
Aviation Support	64	100	-10
Medical	89	100	-8
Logistics	76	87	-9
Administration	89	55	.

^aFrom table 8.

^bFrom table 7.

^cFrom table 3.

This complexity, coupled with the quantity and quality constraints in the model, means that the optimal reassignment need not be the same as the optimal distribution expected by examining one characteristic at a time. Still, there was a strong tendency of that sort in the model anyway. (A close comparison of tables 3, 7, and 8 across the other characteristics taken one at a time will show a pattern very similar to that seen in table 9 for HSGs.)

DISCUSSION

The findings show that the Navy could profitably exploit our 4-year survival estimates when making rating assignments. They imply a first-term retention gain of about 9 percent (6 percentage points) above the actual rate.

This gain estimate may be too high for two reasons. First, the model assigned the entire cohort at once, not one recruit at a time. In other words, it employed perfect foresight. Second, the model assumed that recruits' preferences for ratings would be no more violated by their reassignments than by their original assignments.

On the other hand, although Navy classifiers did not have perfect foresight about the CY 1973 recruit supply when making assignments, neither were they acting in the dark. As for preferences, many of the recruits most able to insist on specific ratings -- the highly qualified 6-year obligors -- were "reassigned" to just those types of ratings.¹ Finally, not all differences in survival effects were exploited in this test (see appendix A). The major ones were exploited. But, to simplify the model, only the average effects of others were included. Had all the differences been used, the gain estimate would have been higher.

Although the gains implied by this test might be slightly too high, there is no reason to assume a drastic overestimate. The results clearly suggest that the Navy could achieve significant first-term retention gains by exploiting the pattern of recruit survival differences across ratings.

Further work is now underway to assess the stability of this pattern for recent recruit cohorts, and to broaden the coverage of Navy ratings. The ultimate goal is to provide rating survival probabilities for recruit classification and assignment that will increase first-term retention.

1

The test did let the model freely allocate about 700 of the 5722 6 YOs available (see table 1). Most of these were sent to the RM/CT group, as a comparison of tables 7 and 8 will show. However, very little of the overall estimated gain results from this. Clear evidence comes from a separate run using a modified version of the model. That version contained no quality constraints at all, BTB or 6 YO. Yet the overall estimated retention rate in that run was 74 percent -- less than one percentage point higher than in the quality-constrained test run. If the 6 YO constraint had been critical to the outcome, we would have seen a markedly higher overall retention rate in the modified version than we did.

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1. Center for Naval Analyses, Research Contribution 382, "First-term Survival and Reenlistment Chances for Navy Ratings and a Strategy for Their Use," by James S. Thomason, Unclassified, May 1979.
2. Burroughs, B 7700/B 6700 Systems, TEMPO, Mathematical Programming System, User's Manual, Burroughs Corporation, 1975
3. Center for Naval Analyses, Study 1039, "Enlisted Selection Strategies," by Robert Lockman, Unclassified, September 1974.

APPENDIX A

COMPUTING SURVIVAL CHANCES
FOR USE IN REASSIGNMENT TEST

APPENDIX A

COMPUTING SURVIVAL CHANCES FOR USE IN REASSIGNMENT TEST

For the reassignment test, recruits were sorted into 48 different input cells. These cells were defined by five variables shown in table A-1.

Eleven variables were used in the initial survival equation (reference 1). They are defined in table A-2. A recruit could have been defined by a distinctive profile (set of values) on each of these 11 variables. Because this would have produced too many input cells for this reassignment test -- more than 3000 -- we aggregated the survival probability estimates to produce 48 cells.

Recruits in each of these 48 cells were available for "assignment" to one or more of 14 rating groups to maximize first-term retention. Each cell (i) was then linked to a given rating group (j) by one average probability (P_{ij}), the expected chance that a recruit from the cell would survive four years if sent to the given rating group. In all, 48×14 P_{ij} s were computed for this test.

The recruits in any input cell might still differ (as indicated by the original survival equations):

1. by race, primary dependents status, and mental ability;
2. by age and education -- e.g., all might be 18 years old or more, but some could be 18, others 19, etc.;
3. by the specific rating, activity, and tour-type they were originally assigned to.

Consequently, each of the 48×14 P_{ij} s was formed in three steps, as follows. First, using estimates from reference 1, we calculated the survival chance for each recruit subtype in cell (i) if sent to group (j), using "intercept" values from the survival equation for specific ratings, activities and tour-types.¹ Secondly, for all recruits in input cell i, if going to group j, we computed the sum of the products of each subtype's survival chance in group j times the percentage of recruits in cell i in the subtype. Lastly, we added to the sum from the second step the average effect -- on the survival chances of a recruit from cell i going to group j -- of specific ratings, activities and tour types within group j (in the

¹The intercept values on these variables differed somewhat by rating group. See reference 1, p. 12, for details.

TABLE A-1

RESCORED VARIABLES USED TO
STRUCTURE MODEL INPUT CELLS

<u>Variable</u>	<u>Rescored values</u>
Age	LT18, GE18 years
Education	LT12, GE 12 years
Delayed entry	yes, no
Boot camp	GL, SD, ORL
Term	4, 6 years

TABLE A-2

VARIABLES USED TO ESTIMATE 4-YEAR SURVIVAL CHANCES
BY RATING GROUP (CY 73 COHORT)^a

<u>Variable</u>	<u>Effects on survival estimated for</u>
Age (at entry)	LT 17, 17, 18, 19, GE 20 years
Education (at entry)	LT 11, 11, 12, GT 12 years
Delayed entry	yes, no
Boot camp location	Great Lakes, San Diego, Orlando
Term of service contract	4 years, 6 years
Race	Caucasian, non-Caucasian
Mental group	1&2, 3U, 3L, 4
Primary dependents	yes, no
Specific ratings	varied by rating group
Activity type	surface combatants, submarine, carrier, repair, etc.
Tour type (rotation duty)	regular sea, toured sea, shore

^aTaken from reference 1, p. 8.

proportions that these characteristics occurred in the original assignment of the CY 1973 cohort).

These three steps yielded one (average) P_{ij} for all recruits from cell i if sent to group j . This process was then repeated for recruits from the same input cell (i) if sent to each of the other rating groups. Finally, recruits in each of the other input cells were in turn linked to each of the rating groups by an average P_{ij} computed in like manner. The resulting set of 48×14 P_{ij} s became the input to the reassignment model.

Several general aspects of this procedure should be noted. First, the proportions of men originally assigned to given ratings, activities, and tour-types within a given rating group were taken as fixed, even if changes in them would have enhanced overall first-term survival for the sample. Such proportions were taken as required by Navy policy.

Second, not all of the other survival differences across ratings that were identified in reference 1 were fully exploited. However, a totally disaggregated set of input cells would have been impractical. And not all variables showed major variation in survival effects across rating groups. Even among those which did (age, education, delayed entry and boot camp), not all differences mattered equally. For example, the main differences in survival effects for age were between recruits less than 18 and those 18 or older. The 48 input cells therefore reflected such divisions. Had all possible values for pre-service and early in-service variables been used, there would have been over 3000 cells and more than 43,000 P_{ij} s to optimize over.

The approach we used was a reasonable middle ground. A more disaggregated one would have increased estimates of the potential gain from exploiting the survival chances. Nevertheless, the results of our test are favorable enough to demonstrate the value of the approach.

